Retracked GDR Release 4.0

Please read these notes in their entirety as there are significant changes from Release 3.0 of April – June 2009 for the Seattle OSTST. In particular, the recommendation about how to make the Sea Surface Height (SSH) with the retracked data has been updated. It may be that this change accounts for strange mean sea level (MSL) behavior of the Alt-A data shown at the 2009 OSTST.

This is a new release of the TOPEX Retracked GDR (RGDR) covering almost all of the TOPEX mission from cycle 21 to cycle 446. There are some missing cycles or batches of passes because valid SDRs could not be obtained. In addition, data for cycles 447 – 485 have not been produced as orbits were not generated (See orbit description from GSFC in Appendix 1; previously they were done by special request). A list of known missing data is given in Appendix 2.

The retracking in this release is the same as release 3.0. The description of the retracking relating versions 2.1 and 3.0 of the RGDRs is given in Appendix 3. MAP retrack (items 124-165) have not been validated (see note 5). No doubt, they still have the features that led to the recommendation not to use them for general analysis. They may have useful properties for some analyses. Analysis of Release 3 data can be found in the presentations and posters of the 2009 OSTST meeting at http://www.aviso.oceanobs.com/fr/courses/ostst/ostst-2009-seattle/ , in particular the Instrument Processing splinter presentation by S. Labroue et al.

The new release 4 RGDRs include
- new April 2010 GSFC orbits (items 7, 8, 10) from GSFC (see email below from Nikita Zelensky in Appendix 1),
- the GOT 4.7 tide model of Richard Ray with interpolation correction (item 61, ocean tide 2, renamed “H_EOT_GOT47”),
- the CLS_01 Mean Sea Surface (for compatibility for Jason; previous versions of the RGDR incorrectly indicated that this was used. Note: **not** the new CLS_10.),
- the TMR Replacement Product (TRP, as in previous releases – not yet updated with coastal processing as the AMR has been for Jason-2/OSTM).

These data are not yet complete as the sea state bias (SSB) and quadrant offsets have not been derived for them. When those quantities are determined (hopefully as part of the Lisbon OSTST meeting in October 2010), the RGDRs will be re-released with those values as well as other available improved corrections. Meanwhile, see point #8 below about adjusting the ionosphere and EMB for the change in SWH, particularly for Alt-A from cycle 140 onward.

The RGDR format is identical to that of Release 3 for 2009 OSTST in Seattle. It attempts to align variable sections on 4 byte boundaries and as many quantities as possible are defined as signed integers. All quantities are scaled integers with as many as possible with a scale of 1. In addition, the RGDRs will soon be released in netCDF that is as similar as possible to Jason-2 data. **Please review the accompanying spreadsheet (retrk-gdr-data-rec-r5-d1.101202.xls) to see the specific filling of each data item; data item numbers are in column E. Note that some fields**

are not computed in this release. This spreadsheet also gives the variable names for the netCDF files that will be released for this version.

The TMR Replacement Product (TRP) released by Shannon Brown http://podaac.jpl.nasa.gov/DATA_CATALOG/tmrinfo.html ((not a new product that goes closer to the coast as produced for the OSTM AMR)) provides a completely recalibrated TMR data set using the methods used to (re)calibrate the JMR for Jason. Note that the corrected Wet_H_Rad_Corr (item 178) is in **0.1 mm**.

The GDR Correction Product (GCP) from several years ago was <u>not</u> used in producing these RGDRs. Thus, some of the fields from that product are missing/defaulted in this release. Those items will be reinstated with the latest models in the final release.

It should be recalled that comparison between TOPEX and Jason during the collinear period (TOPEX cycles 343-364) can be done without geophysical corrections as they are common to the two data sets.

<u>Specific Usage Notes</u>

(Item numbers refer to column B (Field Number) in the Excel spreadsheet retrk-gdr-data-rec-r40r.108.xls .)

1. For items 1-99 if there is no comment, the value is copied from MGDR Version B as distributed by PODAAC/AVISO. The file has a header that is a copy of the MGDR header (33 records) with record length equal to that of the data records = 480 bytes. Values for items that fail retracking are defaulted to the field type maximum (MGDR convention). Spares are defaulted to individual bytes set to 255. An IDL structure for the file is provided on the PODAAC ftp site. A snippet of IDL to read a pass file using the data structure is provided at the end of these notes.

2. POD**:** As indicated in the spreadsheet Sat_Alt_2 (item 10) and all the POD-related quantities have been replaced with the new GSFC POE documented below. Sat_Alt_1 (item 9) is copied from the MGDR. See note 9 on forming high rate Sea Surface Height (ssh_hr).

3. TMR**:** As mentioned in the introduction, Wet_H_Rad_Corr (item. 178, units of 0.1 mm) is from the TMR Replacement Product. Wet_H_Rad_Corr should be used in new sea surface height determinations as it should eliminate calibration drift and yaw (temperature) variations in TMR values.

4. Retracking values are given for the two types of retracking – Least Squares (LSE, Retrk1, items 100-123) and Maximum a Posteriori (MAP, Retrk2, items 124-165) – and K and C bands. The additional items for MAP giving the standard deviations of the fitted variables and flags based on Retracking are defaulted (not valid) on this release.

   MAP fitting is a Bayesian probabilistic approach that reduces to constrained least squares in which the standard deviation about an a priori value is used to condition the solution. See further discussion in Appendix 3.

5. Values for items that fail retracking are defaulted to the field type maximum (MGDR convention). However, individual waveform (WF) retracking flags (WF_Bad_Retrk*_K/C) have not been set based on this assignment, nor has the number of successfully retracked WF per frame

(Nval_Retrk*_K/C, items 110, 122, 134, 146) been determined. Also, computations from retracking, items 170-176 have not yet been implemented.

6. The retracking net instrument correction (K, C – items 168, 169) is

Net_Instr_Corr_Retrk = calib_r_corr + track_mode_r_corr + oscillator_drift_range_corr + doppler_corr

where each term except oscillator drift is found separately for K and C bands.

Unlike the GDR Net_Instr_R_Corr_*, these do not include the dr_SWH_Att or the acceleration correction (which are intrinsically in the retracking estimate).

7. Items 100 (Retrk1) and 124 (Retrk2) are the net instrument range corrections including retracking. The high rate retracked ranges for each frame are compressed to a single value per frame by a least squares bisquare fit (in place of the previous least absolute deviations). The central value is added to net_instr_corr_retrk to give this correction. This effectively replaces the original TOPEX pointing angle/sea state correction (polynomial dr_SWH_Att) with the retracking correction. The slope of the fit and the RMS about the fit are supplied in the record. The high rate deviations from the central value are given in the items *_Hi_Rate.

8. Retracked Sea Surface Height with the new orbit (ssh_retrk) can be produced by using the new satellite altitude and the net instrument correction including retracking to replace the GDR net instrument range correction that uses the tabulated polynomial dr_SWH_Att. Thus, one uses H_Retrk*_K , where * = 1 (LSE, item 100) or 2 (MAP, item 124):

ssh_retrk = Sat_Alt_2(10) – (H_Alt(14) – Net_Instr_R_Corr_K(18) + H_Retrk*_K)
+ Environmental and Geophysical corrections.

Until a new SSB is available, one should consider adjusting the EMB correction in the correction term for the change in SWH, particularly for cycles 140 onward of Alt-A where SWH increased by up to nearly 0.5 m (cycle average). The change in SWH is larger for smaller SWH. Because the GDR Correction Product (gcp) was not used in generating these RGDRs, the recalculated EMB is not directly available. One can approximately adjust the values in items 45, 46 by multiplying those values by (SWH_Retrk1_K(103) / SWH_K(37)).

MGDR ssh (original orbit, instrument corrections (included in H_Alt(14))) is
ssh_mgdr = Sat_Alt_1(9) – H_Alt(14) + Environmental and Geophysical corrections.

9. High Rate retracked ssh with the new orbit (ssh_hr), for each K band waveform in a frame (10 for TOPEX), with the new orbit can be produced by adding the high rate term of each item in ssh (hr = high rate, *=1 or2, (#)= item# in the RGDR spreadsheet):

ssh_hr = sat_alt_2(10) +sat_alt_hr(11) - (H_Alt(14) +H_Alt_hr(15) -Net_Instr_R_Corr_K(18)

+ H_Retrk*_K(100 or 124) +H_Retrk*K_hr(101 or 125))

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Appendix 1: Announcement of New GSFC Orbits

Subject: GSFC Std0905 orbits available for TOPEX/Poseidon, Jason-1, Jason-2
Date: Thu, 1 Apr 2010 16:15:42 -0700
From: "Frank Lemoine" <Frank.G.Lemoine@nasa.gov>
To: "Ocean Surface Topography Science Team" ostst@list.jpl.nasa.gov

Dear Colleagues-

We announce the public release of the std0905 version of the orbits for TOPEX/Poseidon, Jason-1, Jason-2. All orbits are computed using a consistent set of geophysical and modelling standards (std0905) as detailed in the attached memo. The TOPEX and Jason-1 orbits represent significant improvements with respect to the TOPEX GDR-based orbits and the orbits from Beckley et al. (2007).

The orbits are available via anonymous ftp from the web site dirac.gsfc.nasa.gov - as detailed in the attached pdf document. All the orbits carry the designation "std0905"

TOPEX: cd pub/earth/repro_topex/swt09
Jason-1: cd pub/earth/repro_jason/swt09
Jason-2: cd pub/earth/repro_jason/ostm/swt09

To reference these orbits in publications please use the following citation:
Lemoine, F.G., Zelensky, N.P., Chinn, D.S., Pavlis, D.E, Rowlands, D.D., Beckley, B.D., Luthcke, S.B., Willis, P., Ziebart, M., Sibthorpe, A., Boy, J.P., and V. Luceri (2010). Towards development of a consistent orbit series for TOPEX/Poseidon, Jason-1, and Jason-2. Advances in Space Research, DORIS special issue, in review. (A doi number will be available once the review cycle is complete.)

I would like to acknowledge the contributions of the co-authors, the spacecraft teams for TOPEX/Poseidon, and Jason-1 and Jason-2, and the many individual researchers who have contributed to the improvements in the geophysical models that we have employed in these orbit recomputations. These include most significantly, improved gravity models derived as a result of the GRACE mission, improved Earth and ocean tide modeling, improvements to the station coordinates and reference frame thanks to the IERS and POD team colleagues, and improvements to the radiation pressure modelling for Jason-1 developed by colleagues from University College London. We also should not forget the contributions of the International Laser Ranging Service, the International DORIS Service, and the International GNSS Service, without whose data and dedication and continual efforts for improvements, we could not deliver the improved orbit products that we make available today.

In the event of questions please contact Frank Lemoine or Nikita Zelensky:
Frank.G.Lemoine@nasa.gov
nzelensky@sgt-inc.com

Best regards,
Frank Lemoine (On behalf of the entire GSFC POD team)
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Appendix 2: Known missing Retracked Data

cycle	passes
026	195-253
028	131-254
032	253
033	13-29
040	79
050	252-253
054	254
062	1-254
064	254
075	252-254
078	167, 254
083	45, 144, 147, 150, 154-155
087	193, 199
090	254
096	118, 254
099	1
100	1-2, 133-138
101	79, 105
102	254
108	157
109	238-240
111	79, 183
112	108
113	254
115	80, 129-131
117	157-159, 222, 231-254
118	1-254
121	1-3
122	252
123	104-105, 110-183
125	153-155, 254
127	4, 60, 68-72
129	27-105, 133-134, 136-139, 141-145, 147, 149, 151-234
130	76
136	140
137	125, 254
140	91
142	1-2
144	73-77
145	70
147	8, 247-254
148	1-12
149	254
153	121, 127-128, 130-138, 140-159, 162-168
154	1-254
157	245-250
160	41
161	86, 254

cycle	passes
166	216
169	3
170	15
171	254
172	2, 32
173	254
179	56, 254
182	78-80, 133, 254
183	213-216
185	111-114, 254
191	217-220
192	248
196	111-115, 254
208	254
211	194-196
215	179, 254
217	10
219	186-187
220	214-215
223	252-254
225	1
227	10, 145-150
228	252-254
233	254
236	1-61, 66, 85
242	254
244	224
248	1
252	4-5
255	254
258	172
259	215-216
261	41
264	103-109
265	209-234, 254
269	253-254
270	1
274	235
275	129-134
277	254
280	113
283	120
284	161-162
288	1-2, 254
290	1, 15
291	188
298	252-254
301	240
326	107-108
340	1-213

cycle	passes
343	31-33
344	134
345	254
348	35-36 [217-254 BB]
349	113
350	[1-6 BB], 180
353	58-65, 70-78
354	254
355	1, 45

359	76
360	254
362	6, 36, 78
365	59-60, 90, 102-103, 112, 127-129, 190, 214-254
366	1-61, 93
367	218-219
368	1-18, 94, 170
370	94-97
371	45, 47-48, 88, 114, 148-150, 156, 174, 199-200, 216, 227, 233, 244
372	49, 66, 90, 92, 194, 244
373	42, 53, 102, 118
374	27, 213, 254
375	3, 11-24, 29, 55, 133, 218
377	254
378	53
379	3, 14, 105, 142, 168
380	194
390	183, 254
398	1
400	1-143
404	179
406	71, 73
407	182, 244
408	47-52, 54-72, 74-79, 82-93, 95, 97-99, 101, 135-158
409	18, 97-103
411	106
412	1-254
413	1-67, 139-254
416	1-254
418	1
419	199
421	84-254
422	1-61
427	3, 6
430	171, 253-254
431	1-254
432	1-254
435	217-254
436	1-254
437	221-254
438	61
439	69

cycle	**passes**
442	34
443	18, 23-26, 82, 155-159, 246
446	88

Cycles 447 – 485 (POD not currently available)

Appendix 3: Discussion of Retracking for RGDR Versions 3, 4

The retracking in this release is the same as release 3.0. The Retracking was done with the software used for the Release 2.1 data of 2007 which gave consistent results between TOPEX and Jason-1 MLE4. The major change from 2007 is that an automated procedure to fit an altimeter point target response (PTR) to the calibration data of each cycle was used. This was crucial for correcting the PTR changes in Alt-A from about cycle 140 onwards. The PTRs used here were extended +/-12 sidelobes (final amplitude ~ 0.001 = -30 dB) although the 2007 analysis suggested that +/-50 might be needed to get the most consistent results. Investigation with PTRs extended to +/-30 sidelobes showed very small differences in range and SWH; the only notable change was slightly smaller attitude values with the larger PTRs. Also, the gain factors or "weights" for this retracking were adjusted slightly from those used previously to reduce waveform residuals. The same set of weights was used for all processing. Comparisons of data retracked with the same PTR and 2007 and 2009 weights showed essentially no dependence on the weights for range and wave height (SWH) with some change in the skewness which is the parameter that collects the TOPEX waveform artifacts. Comparisons with various PTRs showed variations up to +/- 10 mm around the data provided here on the cycles examined. All of the experimental cases showed similar dependence on SWH of differences (i.e., sea state bias, SSB) between retracked and GDR values.

Analysis of Release 3 data can be found in the presentations and posters of the 2009 OSTST meeting at
http://www.aviso.oceanobs.com/fr/courses/ostst/ostst-2009-seattle/ ,
in particular the Instrument Processing splinter presentation by S. Labroue et al.
The analysis shows a significant change in the relative SWH behavior of these data in the Jason-1/TOPEX collinear period from the 2007 data. In addition, the retracked data for Alt-A no longer show the expected approximately linear trend in global sea level that the Alt-B and Jason-1 data show. The cause(s) of these changes in behavior are under continuing study.

Figure 1 shows the expected correction of the GDR SWH drift caused by the change in PTR that started about cycle 140 and reached nearly 0.5 m before the switch to Alt-B. Alt-B SWH is consistent with early Alt-A in both the GDR and retracking. Retracked SWH shows a small bias (< 0.1 m) compared to the GDR.

Figure 2 shows the change in the net instrument range correction between retracking and GDR. Other than the orbits, this is the main change affecting sea surface height of the RGDRs from the GDRs. The ~15 mm change at the end Alt-A from about cycle 180 onwards is expected as the GDR used the erroneously high SWH values in the Pointing Angle/SWH tables and thus got incorrect values. Figure 2 shows that the data for cycles 344-364 seem to be slightly different than the overall for Alt-B (as noted in the CNES study), but not outside of the overall variations. The reason(s) for the small differences in the TOPEX/Jason-1 collinear period is not clear at this time. Depending on additional findings by the OSTST and in particular the fitting of the sea state bias (SSB), some reprocessing of the TOPEX data may be considered.

Maximum A Posteriori (MAP) fitting is a Bayesian approach that reduces to constrained least squares in which the standard deviation about an a priori value is used to condition the solution. Prior values from smoothing over 25 points of the LSE solution were used for SWH, and Attitude. The a priori skewness was set to 0 as it was determined that the LSE value was too noisy even with smoothing. No prior value or constraint was used for Range. The standard deviations were set at

std_dev_prior = sqrt(std_dev_min^2 + std_dev_smoother^2))

where the std_dev_min values are SWH = 0.5m, Attitude = 0.002deg, Skewness = 1.0, and the std_dev_smoother is the RMS of the values within the smoothing window of the quantity.

The MAP estimates are much smoother than the LSE values (as expected), giving a time series similar to the smoothed LSE solutions. We do not believe that the above values of standard deviation are overly constraining, but additional testing will be done. It should be remembered that the skewness values for TOPEX are not representative of the ocean surface because of the leakages in the waveform.

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Selected MAP References from a Google search for maximum a posteriori fit:

http://www.numerica.us/papers/PooreSlocumb_spie2003.pdf
A.B. Poole, B.J. Slocum, B.J. Suchomel, F.H. Obermeyer, S.M. Herman, S.M. Gaaleta 2003, SPIE, "Batch Maximum Likelihood (ML) and Maximum A Posteriori (MAP) Estimation with Process Noise for Tracking Applications".

http://www.stat.lsa.umich.edu/~ionides/pubs/msle.pdf
E. L. Ionides 2005, Statistica Sinica, **15**, 1003-1014, "MAXIMUM SMOOTHED LIKELIHOOD ESTIMATION".

http://www.cs.pitt.edu/~milos/courses/cs2750-Spring03/lectures/class12.pdf

http://www.ee.washington.edu/research/isdl/papers/droppo-1998-icslp.pdf
James Droppo1 and Alex Acero 1998, Proceedings of the 1998 ICSLP Australia, **3**, 943-946, "MAXIMUM A POSTERIORI PITCH TRACKING".

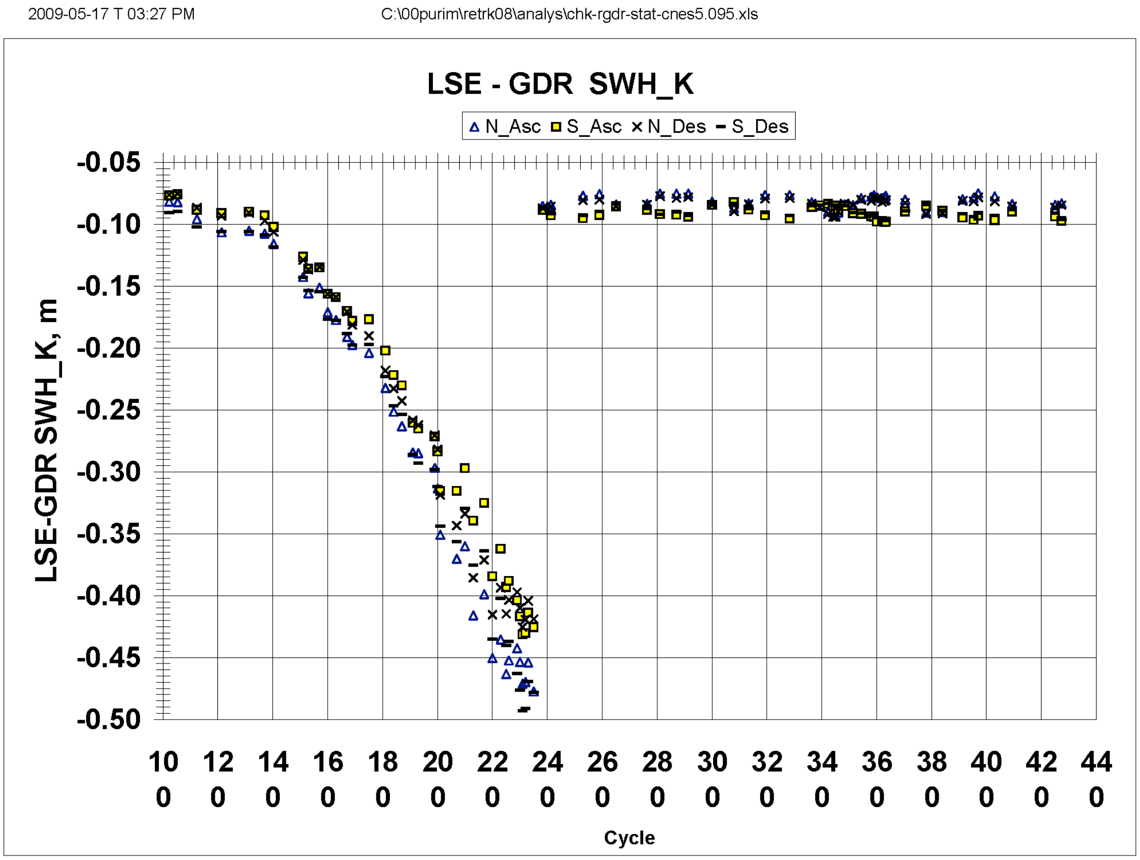

Figure 1: Change in SWH from LSE (Retrk1) retracking relative to GDR. This shows the effect of the PTR change toward the end of Alt-A. Early Alt-A and Alt-B data are very consistent. The different symbols are the “quadrants” of data: North/South Ascending/Descending as TOPEX quantities depend on range rate because of movement of the waveform leakages.

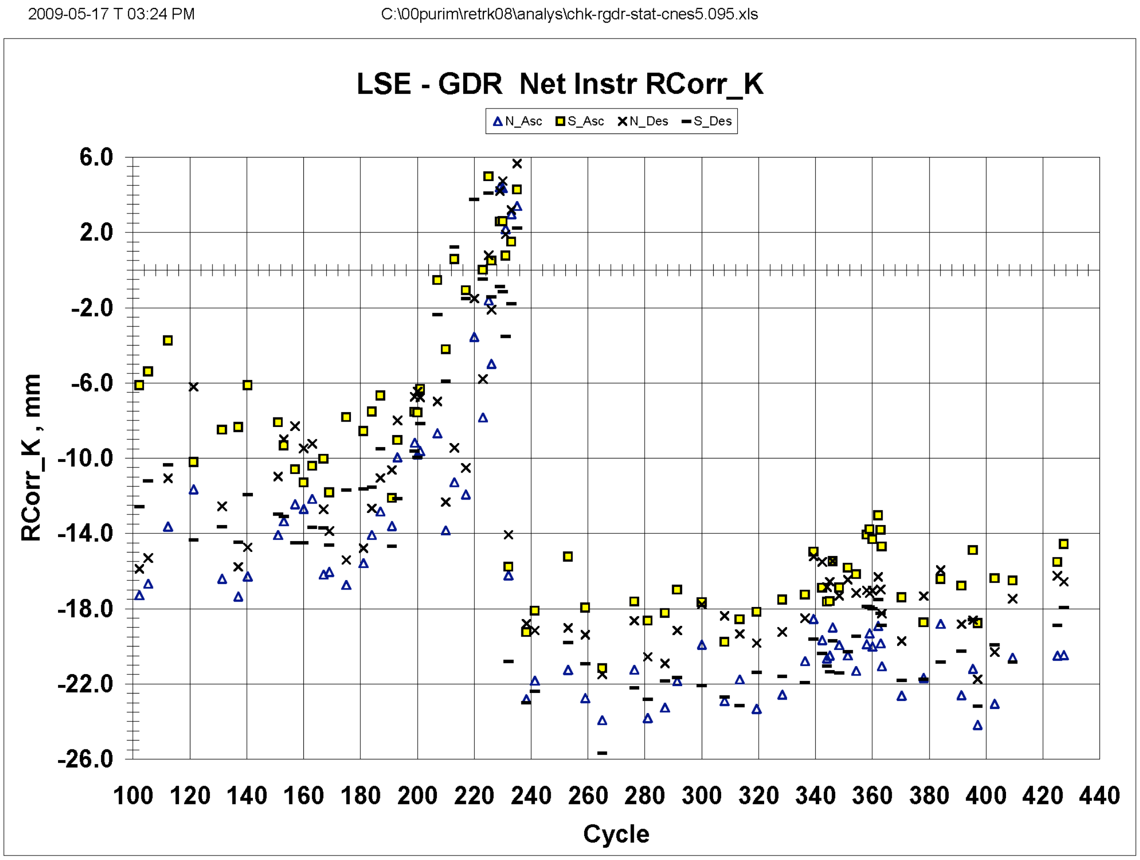

Figure 2: Change in net instrument range correction from LSE (Retrk1) retracking relative to GDR. This shows the effect of the PTR change toward the end of Alt-A and a small difference during the TOPEX/Jason-1 collinear period. The difference between the quadrants is apparent at the 4 mm level. The slope over the Alt-B period is about 0.3 mm/yr; note that this includes both the original and interleaved ground tracks.

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Appendix 4: Example IDL Reading of RGDR

IDL Pass reading example (cycle 355, pass 022) using structure in rgdr09__define.pro (contains named structure rgdr06)

```
rec_len  = 480
nrec_header = 33

; Form file spec:
rgdr_path = '/home/psc/tpx_retrk/dat/cyc355/rgdr/'
ccycle = '355'
cpass = '022'
inrgdr = rgdr_path + 'retrkgdr_' +ccycle + '.' +cpass   ;

print, inrgdr

close, 1   ; just to be sure
openr, 1, inrgdr, /swap_if_big_endian   ; RGDRs are little endian (PC)
file= fstat(1)   ;  get some info about file inrgdr on unit 1
;
nrecrg = file.size/rec_len -nrec_head   ;  number of data records
nptsrg1 = nrecr -1   ;  max index
print,' File size, rec leng, expected records : ', file.size, rec_len,
nrecrg

; Create vector of rgdr structure rg(0:nptsrg1).rgdr_structure
;  from rgdr09__define.pro .  Structure name in __define is rgdr06.
rg = replicate({rgdr06d}, nrecrg)

; Put file pointer at data past header
point_lun, rec_len * nrec_header

readu, 1, rg   ; reads data in vector-structure

close, 1
```